7 - 12 SEPTEMBER 2014, KRAKÓW
FORUM ACUSTICUM

The uncertainty of sound insulation properties of light weight building elements

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Summary
Measurement uncertainty is an important topic in building acoustics measurements carried out in the field assessing the sound insulation between rooms as well as conducted in test stands characterizing the sound insulation properties of a building element accurately. Beyond measurement method related contributions to the uncertainty budget there is the variation of the sound insulation properties of the building element itself. According to several studies conducted in the past this uncertainty due to the building element properties can be of a significant quantity. The results of a recent study show that certain aspects of workmanship have significant influence on the sound insulation characteristics of light weight building elements, e.g. timber frame partitions. The method to fasten the planking (e.g. gypsum boards, gypsum fiber boards or chipboards) can lead to considerable variations regarding the sound insulation characteristics and thus to influence also the single values, with variations of the sound reduction index R_w of up to 10 dB. The mounting (i.e. the arrangement of the screws) has considerable influence on the sound insulation properties of this kind of partitions. The airborne sound insulation can be significantly influenced by the number of the screws and by the degree of how firmly they are fixed. The influence of construction details, workmanship, and suggestions how to face this problem will be discussed in the paper.

PACS no. 43.55+p.Nn, 43.40+s.Nn

1. Introduction

The total uncertainty of sound insulation measurements carried out in the field or conducted in test stands are not only determined by the variability due to the degree of accurateness of the measurement instruments and of the measurement methods [1, 2], but also by the variability due to workmanship [3]. Light weight building elements, such as partitions with timber studs, show a large variation of sound insulation properties although many of them differ only in very few and from the building acoustics point of view seen as ”secondary” construction details. This problem is a rather big challenge for the lightweight- and building with wood industry.

Several studies (e.g. [4, 5, 6]) show that beyond measurement instruments’ and test method related uncertainties, the way how accurately the element is produced can have a considerable influence on the sound insulation characteristics of building structures. The way to fasten the planking can lead to large variations regarding the sound insulation performance. Those uncertainties have to be sufficiently investigated, determined and indicated if reliable predictions of the sound insulation properties of the buildings have to be obtained in order to meet the requirements with a high accuracy.

In this work the workmanship related sound insulation uncertainty of a basic timber frame partition is investigated. The influence of the number of screws and the degree how firmly the planking is fastened to the studs on the sound reduction index of the lightweight building element is studied experimentally. Different

arrangements of the screws for fastening the planking onto the timber frame of a light weight building element are considered. In all cases only the arrangement of the screws had been changed, all other elements had been kept the same.

2. Test set-up

The experiments were carried out in a test stand for air borne sound insulation measurements according to ISO 10140-5 [7] regarding ISO 10140-1 [8].

The partition under test consisted of 160 mm / 80 mm timber studs (mounted with a center distance of 625 mm) and of 12.5 mm gypsum fiber boards on both sides connected by screws. The remaining gap between the panels was entirely filled with glass wool of 12.5 kg/m^3 material density. The vertical butt joints were sealed by a jointing compound as recommended by the gypsum board producer's guidelines.

For this study applying screws has been preferred because it was considered to be handled easier in order to prepare controlled experimental conditions compared to staples. Nevertheless the findings can be applied for the fastening by staples as well according to preliminary tests done before the experiment reported in this paper. For the first experiment condition the gypsum fiber boards were only fixed at the top and at the bottom of the stud. For the second turn screws were applied on the height of the horizontal line in the middle of the partition. For the next arrangements the screw distances have been successively decreased always by half ending with the smallest distance of approx. 31 cm. For the first part of the test series the screws were firmly fixed. For the second part of the experiment the same distance arrangements were investigated but with the screws approx. one half turn back from the firmly fixed position.

3. Results

The sound reduction index R for the investigated conditions was measured according to ISO 10140-2 and -4 [9, 10]. The weighted sound reduction index R_w and the spectrum adaptation terms C, C_{tr} were determined according to ISO 717-1 [11].
The arrangement of the screws and the variation of the degree how firmly they are fixed have a significant influence on the sound insulation properties of the partition tested.

Differences have mainly been found in the frequency range above 160 Hz. In the frequency range above 200 Hz differences of about 10 dB were obtained. For detailed results see [14].

For the firmly bolted arrangement the single number values of the weighted sound reduction index are R_w = 58 dB (least screws) and R_w = 48 dB (most screws, screw distance approx. 31 cm). The conditions with less firmly bolted connections the sound insulation was higher in general in comparison with the firmly fixed conditions (R_w = 58 dB, screws only at the top and at the bottom of the wall, and R_w = 52 dB with the most screws, distance between the horizontal rows approx. 31 cm).

4. Conclusions

According to the results, workmanship how the planking is connected to the timber studs can cause a considerable large difference of the sound insulation properties of timber frame partitions.

The experiments showed that currently practically applied variations of arrangements of the screws of timber frame walls can lead to a large variability of sound reduction indexes which is significantly larger than the range of the sound insulation categories of the recently established classification schemes e.g. for dwellings in Austria (cf. [12]).

Above 200 Hz the sound reduction index R can differ more than 10 dB caused by the variation of the number and distance of the screws. With the same vertical screw distance firmly fastened screw arrangements lead to much lower sound insulation values than less firmly screwed panels (approx. one half turn back from the firmly fixed situation). Similar variations have been found by investigations of the interaction of the number and position of screws with gypsum board walls with steel channels [4, 5]. In these studies the position of the screws caused a variation of the weighted sound reduction index R_w up to 6 dB. These findings have been confirmed recently [6]. The repeatability value r as a function of frequency for light weight gypsum board walls according to [1] doesn't exceed 1.5 dB, thus most of the extent of uncertainty can be considered as caused by workmanship aspects.

The degree of the influence of the workmanship on the sound insulation as shown by the experiments underlines the problem which occurs for the development of accurately applicable prediction models for this kind of building elements to get on a construction quality level without the currently mainly applied try and error approach. Thus the effect and interaction of the construction details influenced by workmanship have to be investigated to be able to provide a modeling approach which concerns this considerable uncertainty. In addition to the standardized measurements of the sound reduction index *R*, extensive experiments have been carried out by means of a scanning laser Doppler vibrometer (LDV) [13]. Beyond the aim testing the technically and economically applicability of the LDV-method, basic data regarding the interaction of studs and of the fastening details with the planking have been gathered. First basic findings which will support the next steps in developing approaches for prediction models are reported in [14].

The development and implementation of robust design solutions should be stimulated as suggested in [15]. In regard to the robust detail approach [15, 16], mounting conditions have to be investigated thoroughly and strictly described in the production guidelines and quality system procedures to ensure sound insulation properties with a small range of uncertainty.

This extend of possible uncertainty shown by this study supports the approach discussed in [16] where mandatory inspection and monitoring (in the factories and on site) are considered as indispensable in order to ensure the sound insulation properties of building elements and buildings as long as there are no accurately predictable light weight building systems or approaches according to the robust detail concept.

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